International Journal of Electrical and
Electronics Engineering Research (IJEEER)
ISSN(P): 2250-155X; ISSN(E): 2278-943X
Vol. 7, Issue 1, Feb 2017, 1-12

PERFORMANCE ANALYSIS OF INSTANTANEOUS HARMONIC POWER THEORY BASED ACTIVE POWER FILTER UNDER DIFFERENT LOADING CONDITIONS

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ABSTRACT

In Distribution system the non-linear loads and use of power electronics based equipment's are raised. Due to the increase of non-linear loads drawing non-sinusoidal currents and generate harmonic current at PCC, which may deteriorate the power quality. In distribution system this distortion has become a serious problem in electrical power systems. In this suggests a method that consists of 3-leg inverter i.e. capable of compensate current imbalance and harmonics presented in system. This setup named as Active power filter (APF) is shunted to inject power into System. The inverter is actively controlled in such a way that it draws/supplies fundamental active power from/to the Industrial loads. The effectiveness of the filter depends on its control strategy. This work instaneous harmonic power is used for compensation of harmonics. All of these functions may be accomplished either individually or simultaneously. Here the system is connected with industrial loads. Matlab/simulink based system setup is developed and performance of APF is showed at load is constant, increment in load and decrement in load conditions.

KEYWORDS: Active Power Filters (APF), Current Imbalance, Harmonics, Power Quality Problems and Nonlinear Loads

Received: Nov 24, 2016; **Accepted:** Dec 17, 2016; **Published:** Dec 21, 2016; **Paper Id.:** IJEEERFEB20171

Original Article

1. INTRODUCTION

Modern electrical systems, due to wide spread of power conversion units and power electronics equipment's, causes an increasing harmonics disturbance in the ac mains currents. These harmonics currents causes adverse effects in power systems such as overheating, capacitor blowing, motor vibration, excessive neutral currents, resonances with the grid and low power factor. As a result, effective harmonic reduction from the system has become important both to the utilities and to the users [1].

The solution over passive filters for compensating the harmonic distortion and unbalance is the shunt active power filter (APF). The APF is actually an inverter that is connected at the common point of coupling to produce harmonic components which cancel the harmonic components from a group of nonlinear loads to ensure that the resulting total current drawn from the main incoming supply is sinusoidal [2].

Based on harmonic voltages classified into two categories:

- Background harmonics
- Additional harmonics

When harmonic Sources are connected to network Background harmonics are existed.

These two types of harmonics generated by harmonics source connected to network back ground harmonics existed. Additional harmonics produced at PCC.

We need to compensate the two types of harmonics; here the compensation is done by Active Power Filter (APF). For harmonic mitigation APF is good tool, as well as reactive power Compensation. The instaneous power recover theory is used to extract the harmonic content from power circuit configuration. Considerable efforts have been done in recent years to improve the management of harmonic distortion in distribution systems [3].

The Changing in loads concurrently able to adapted, can be expanded easily and will not affect neighborhood equipment's. In order to compensate the distorted currents the APF injects currents equal but opposite with the harmonic components, thus only the fundamental components flows in the point of common coupling (PCC) as in equation (1): if = ilh, h=2; where h is the order of the harmonic & il is the load current.

Active power filter (APF) should be capable of nullify the variations in component of instantaneous power and also the reactive power of fundamental frequency. A simple control strategy called instantaneous harmonic power theory can control the APF by defining instantaneous active power and reactive powers. The defined powers will apply to controller or apply in either the αβ0- or dq0-domains and for balanced sinusoidal three-phase systems would yield constant values. There are various representations of the equations such as complex power or a two-dimensional cross product [4-6].

In this paper the APF connected with Distribution system with Non-linear loads or industrial loads connected, Matlab/Simulink based model is developed. The APF performance evaluated under different conditions of loading on system is showed.

2. ACTIVE POWER FILTER CONFIGURATION

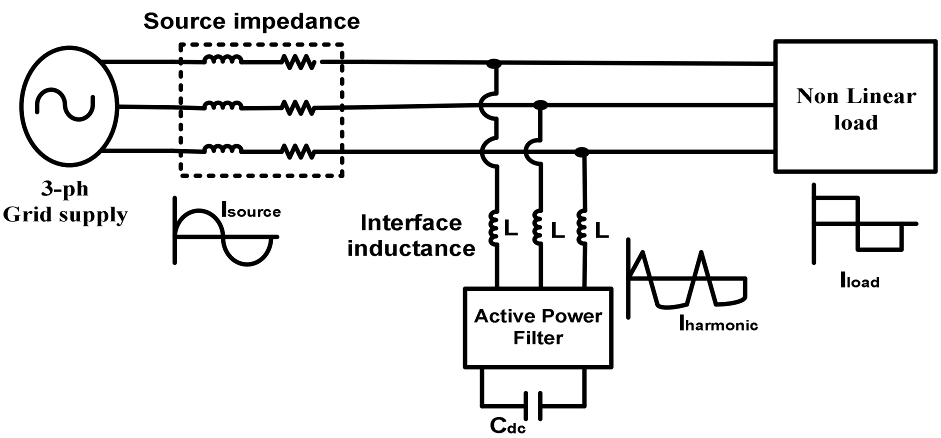

Figure 1: Block Diagram of APF Connected in Distribution System

The figure 1 shows the Basic structure of a Active power filter (APF) connected with system. Basically we have two types of Active filters are shunt and series type connected filters. It is possible to find active filters combined with both passive and active filters acted together. The series APF does not compensate for load current harmonics but it act as high impedance to the current harmonic from power source side. So we moved to shunt APF for compensating the load current harmonics. This Shunt APF is able to compensate for both current harmonics and reactive power. APF is a voltage source

inverter with only single in dc side controlled in similar way it act as current source, here the APF does not require any power source here [7] [8].

The three phase voltages (Va, Vb, Vc) and currents (iea, ib, ic) is measured is given to load. For controller the reference current taken as (ica*, icb*, icc*, icn*) is used to produce compensation current (ica, icb, icc, icn) from APF. The end of system is connected with Non-linear load and at PCC have APF.. This APF filter generates Compensating currents of the non-desirable current components in the load current.

2.1 APF Connected to Industrial Loads

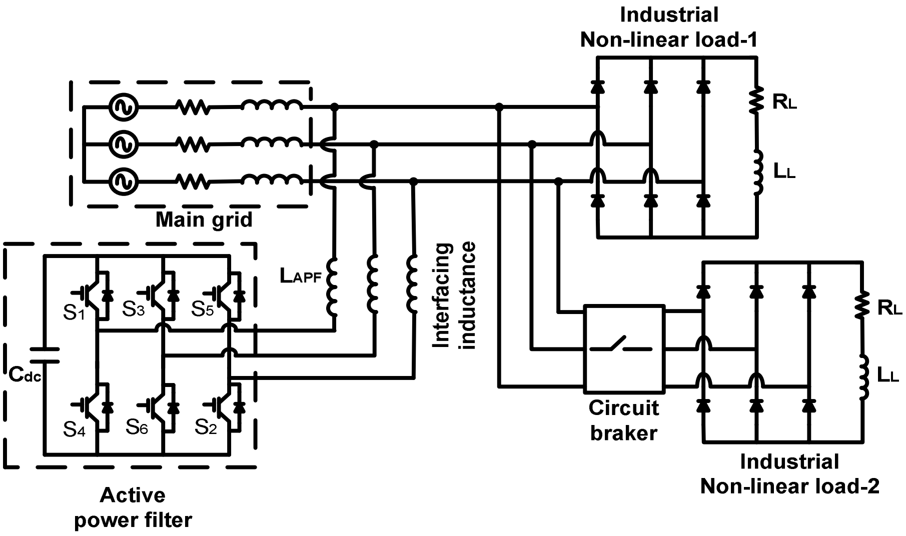

Figure 2: Active Power Filter for Compensation of Harmonics Industrial Load

Figure 2 shows the block diagram of Active power filter is tethered with two industrial loads, one is directly connected another one is connected with breaker. Point of common coupling is shunted with APF is having with voltage source converter through interfacing inductor (L_{APF}). The three phase AC source is fed supply to industrial load, due non-linear type of loads current harmonics will be generated and reactive power is demand is raised. The three leg APF is shunted is generate compensating currents to mitigate the harmonics produced in system [9]. Here the APF performance is evaluated under three conditions at constant load increased loading and decreased loading conditions.

3. INSTANEOUS HARMONIC POWER COMPENSATION THEORY (IHP)

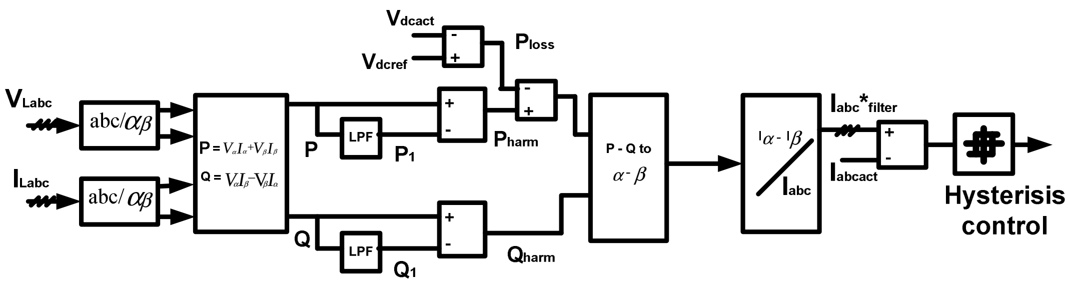

Figure 3: Instantaneous Harmonic Power Compensation Theory

The instantaneous Harmonic power theory is widely used to design controllers for active power filters. This paper deals with some problems due to the harmonics produced from different industrial loads connected in distribution system.

A historical background of the theory is presented and the problem caused by distorted voltages at the point of common connection (PCC) is analyzed. In addition, the emergence of source current harmonic component not present in the load current (hidden current) caused by different filtering characteristics for the calculation of the oscillating real and imaginary power components is discussed. The problem caused by the voltage distortion can be solved using a phase locked loop (PLL) circuit. For the hidden current, filters with similar characteristics can avoid them. These analysis and solutions are presented to clarify some aspects of the p-q Theory not clear in the original approach of the theory [10].

The p-q Theory is based on the αβ0 transformation, also known as the Clarke Transformation, which consists in a real matrix to transform three-phase voltages and currents into the αβ0 stationary reference frame. One advantage of applying the αβ0 transformation is the separation of zero-sequence components into the zero sequence axis. Naturally, the α- and β-axis do not have any contribution from zero-sequence components. If the three phase system has three wires (no neutral conductor), no zerosequence current components are present andi0 can be eliminated in the above equations, simplifying them. The present analysis will be focused on three-wire systems

3.1 APF Controlling with IHP Theory

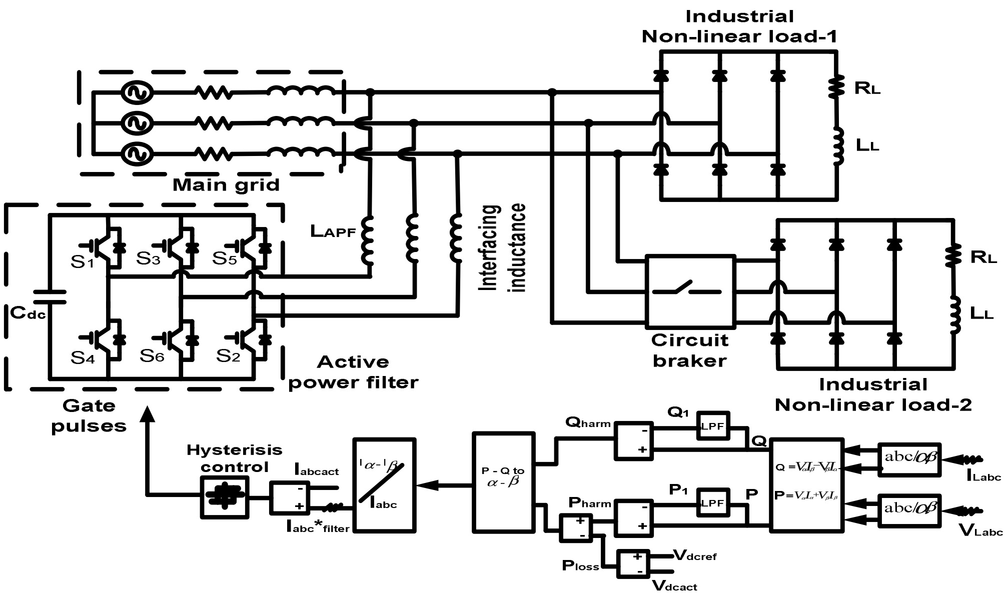

Figure 4: Complete Block Diagram of Instantaneous Harmonic Power Theory Based APF

Figure 4 shows the basic instantaneous harmonic power theory based APF commonly used for the calculation of the compensating currents for APF. In this figure, it clearly explains the powers p and q are the compensation reference powers. In this paper instantaneous harmonic power theory is used to control the compensating currents to the system. Here reference compensating powers will generated from actual values of voltage and currents, is then formed into active and reactive powers. These powers are passed through LPF, the is compared with power loss finally harmonic power generated is then converted into αβ0 transformation. This is compared with filter current flows through hysteresis controller the APF gate pulses will generated. Many methods were available to generate control signals but simplicity of instantaneous harmonic power theory makes the design easy. This paper discusses the effectiveness of APF to mitigate the harmonic pollution in the system by generating compensating currents through IHP control theory. Model of the above said system was build for a 440 KV system with non-linear load. In general, when the load is nonlinear the real and imaginary powers can be divided in average and oscillating components.

4. MATLAB/SIMULATION RESULTS

4.1 Constant Load

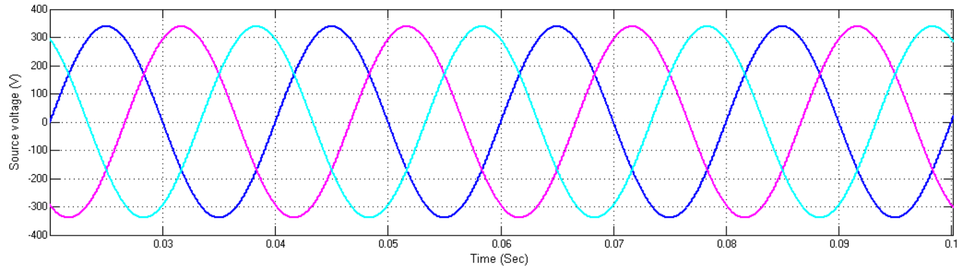

Figure 5: V_{PCC} Voltage of APF

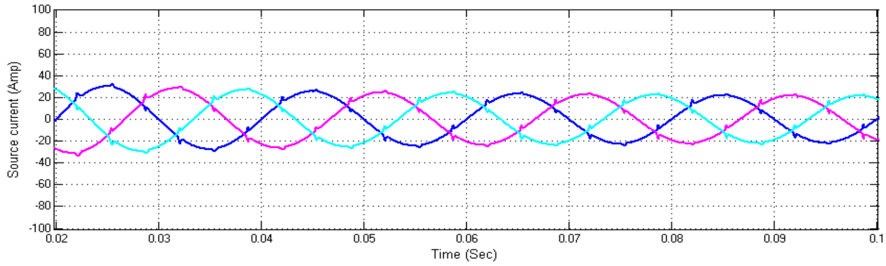

Figure 6: Source Current of APF

Figure 5 & 6 shows three phase source voltage and Source current having with an peak magnitudes of 325V and 30A. From the figure it is clear that the VPCC voltage & Source current are sinusoidal.

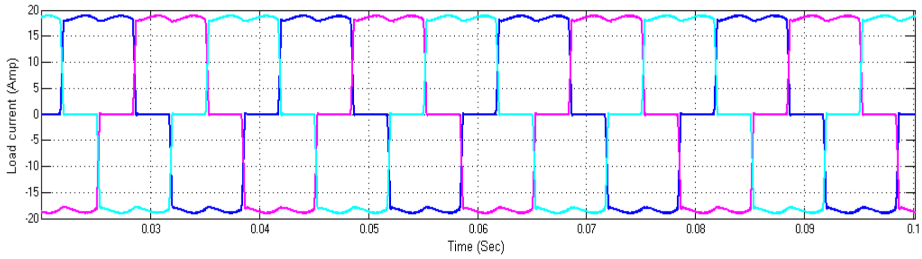

Figure 7: Load Current due to Harmonic Load

Figure 7 shows the load current waveform constantnon linear load connected in Distribution system, the peak amplitude is 18A. Due to non linear load nature the current shape is square wave and it contains harmonics.

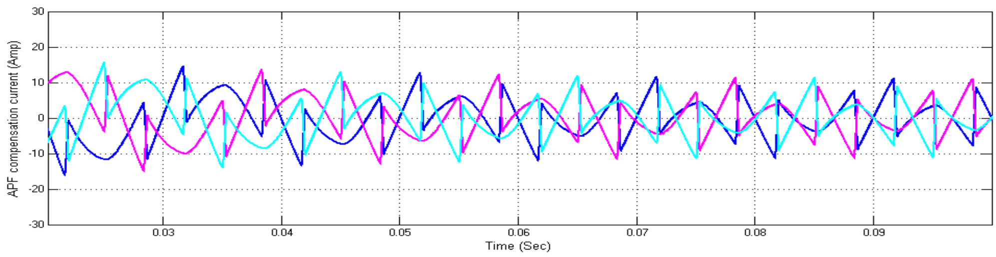

Figure 8: APF Compensation Current

Figure 8 shows the compensating APF current waveform is shwed atconstant nonlinear load connected in Distribution system. APF supplies the harmonic current to load, such that source current is sinusoidal.

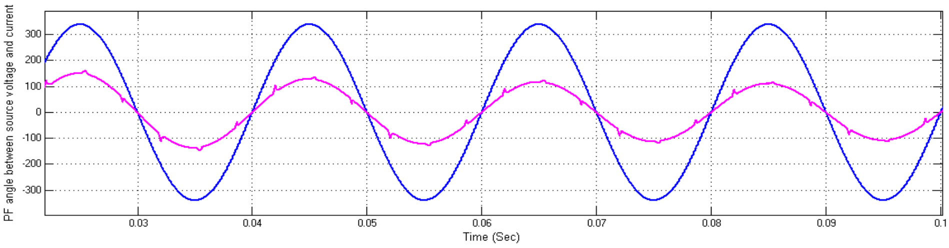

Figure 9: Power Factor

Figure 9 shows the Power Factor waveforms at Constant Non linear load connected in Distribution system. Here the power factor is maintained around unity

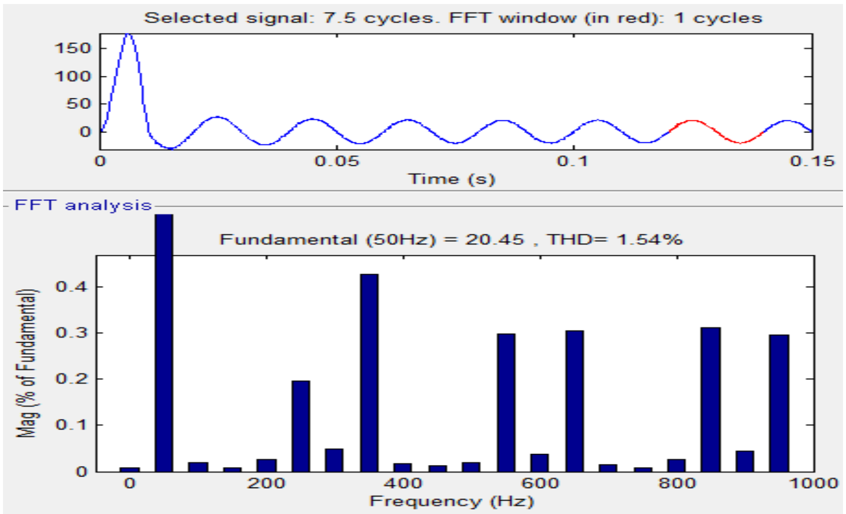

Figure 10: Source Current THD

Figure 10 shows the source current THD waveforms at constant Non linear source connected in Distribution system. The THD presented in load current is 1.54%.

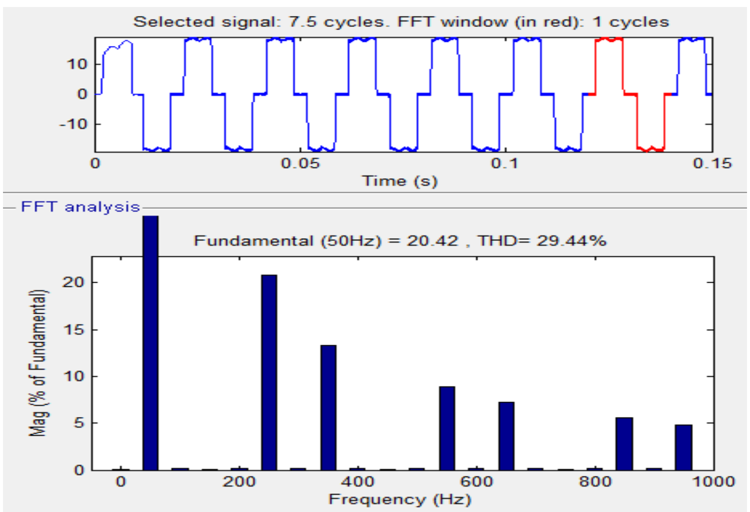

Figure 11: Load Current THD

Figure 11 shows the Load current THD waveforms at constant Non linear load connected in Distribution system. The THD presented in load current is 29.44%.

Performance of APF with Sudden Increment in Load

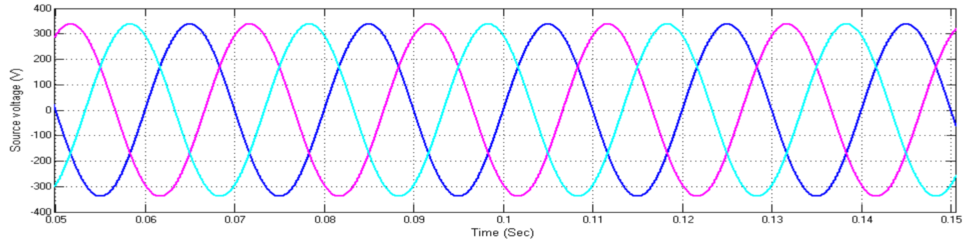

Figure 12: V_{PCC} voltage of APF

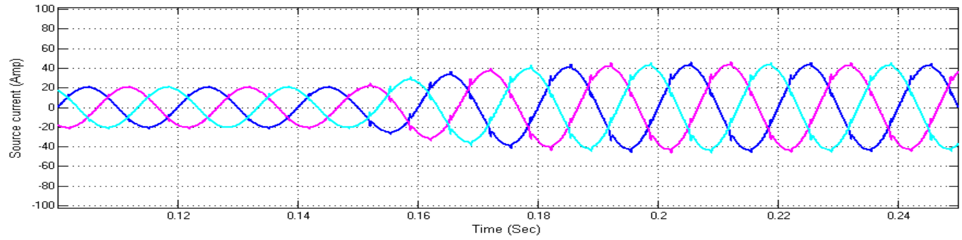

Figure 13: Source Current of APF

Figure 12 & 13 shows three phase source voltage and Source current having with peak magnitudes of 325V and 20A. Source current is raised to 40A at 0.5 sec is continued to till end.

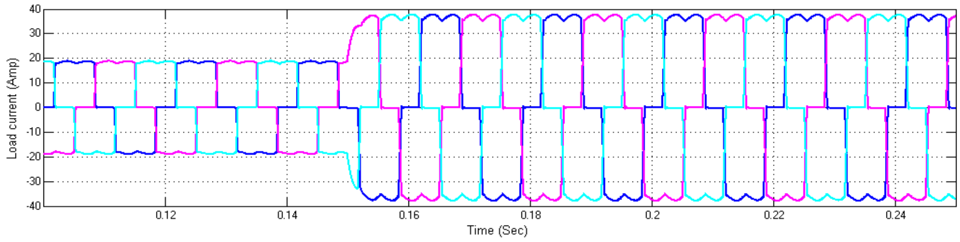

Figure 14: Load Current

Figure 14 shows the load current waveform increasednon linear load connected in Distribution system, the peak amplitude is 20A, at 0.5 sec the load across system is increased due to this load is suddenly rised to 40A. Due to non linear load nature the current shape is square wave and it contains harmonics.

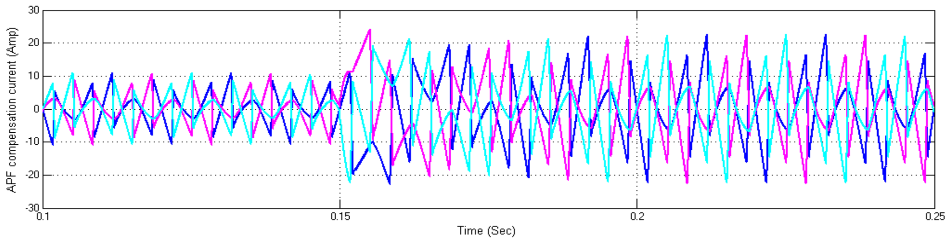

Figure 15: APF Compensation Current

Figure 15 shows the compensating APF current waveform is shwed atIncremental nonlinear load connected in Distribution system. APF supplies the harmonic current to load at 0.15 is suddenly raised to 15A..

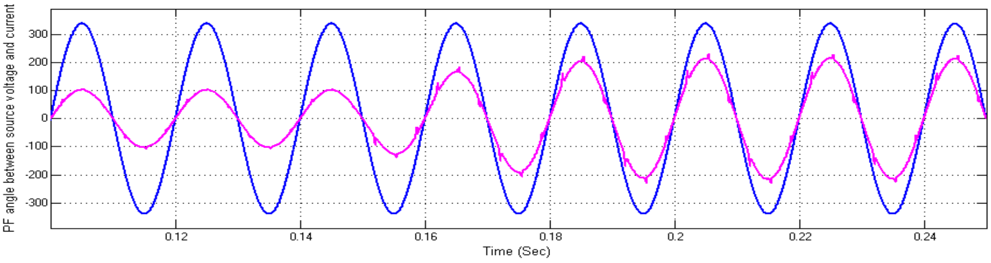

Figure 16: Power Factor Angle at Increased Load

Figure 16 shows the Power Factor waveforms at increased Non linear load connected in Distribution system. Here the power factor is maintained around unity

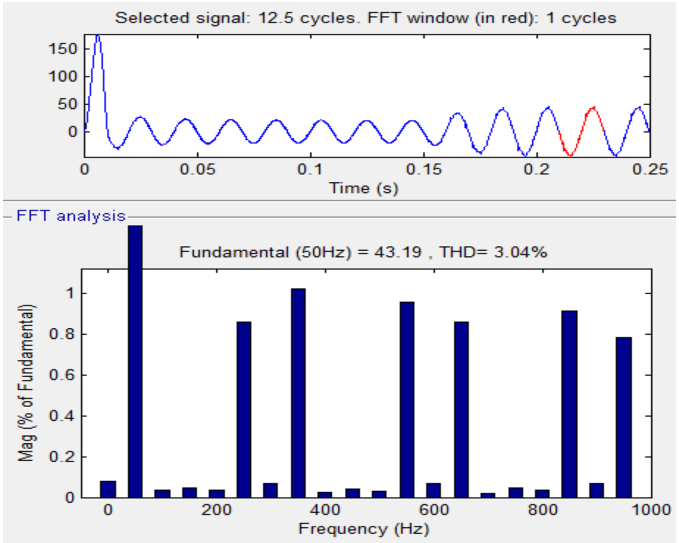

Figure 17: Source Current THD

Figure 17 shows the source current THD waveforms at increased Non linear source connected in Distribution system. The THD presented in load current is 3.04%.

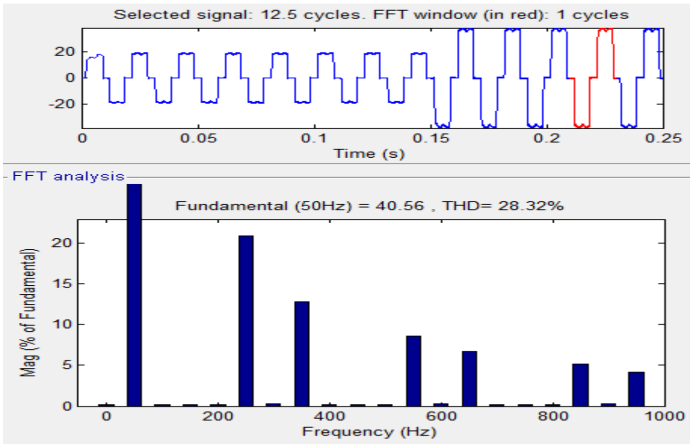

Figure 18: Load Current

Figure 18 shows the load current THD waveforms at Increased Non linear load connected in Distribution system. The THD presented in load current is 28.32%.

Performance of APF with Sudden Decrement in Load

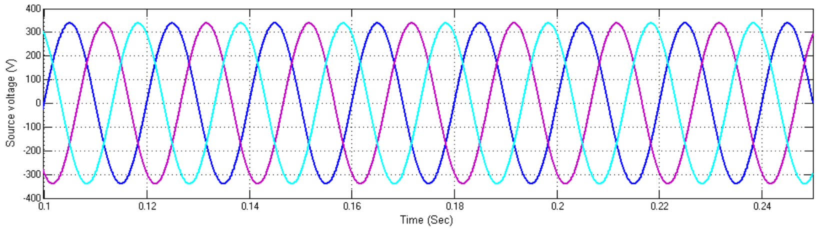

Figure 19: V_{PCC} Voltage of APF

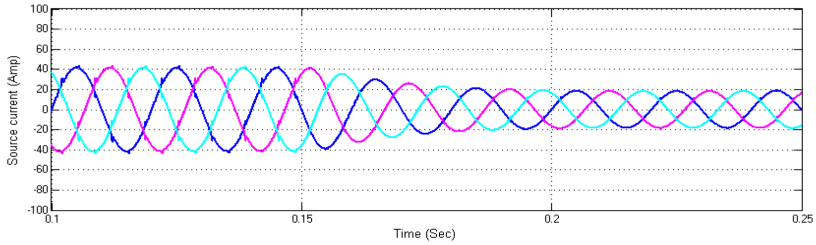

Figure 20: Source Current of APF

Figure 19 & 20 shows three phase source voltage and Source current having with peak magnitudes of 325V and 40A. Source current is fall down to 20A at 0.5 sec is continued to till end.

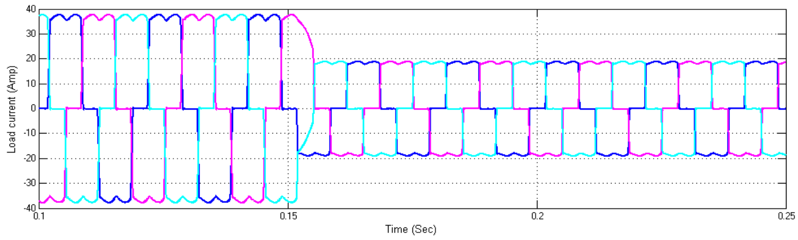

Figure 21: Load Current

Figure 21 shows the load current waveform decrementalnon linear load connected in Distribution system, the peak amplitude is 40A, at 0.5 sec the load across system is decreased due to this load is suddenly rised to 20A. Due to non linear load nature the current shape is square wave and it contains harmonics.

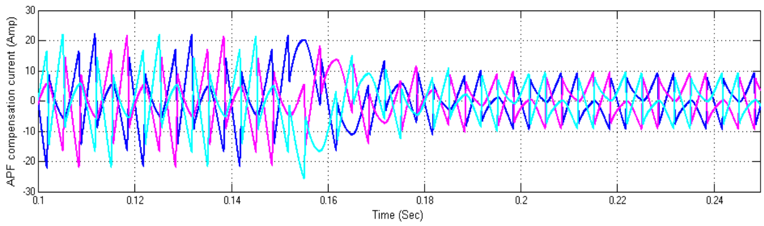

Figure 22: APF Compensation Current

Figure 22 shows the compensating APF current waveform is showed at decreased nonlinear load connected in Distribution system. APF supplies the harmonic current to load at 0.15 is suddenly fallow to 10A..

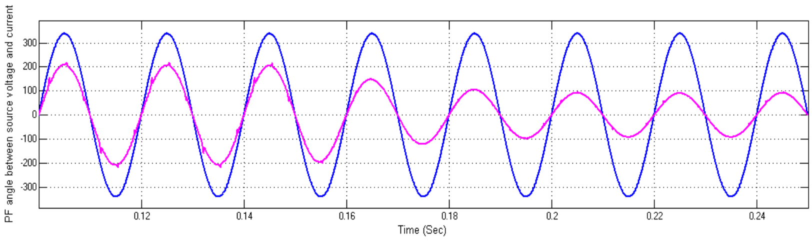

Figure 23: Power Factor at Decreased Load

Figure 23 shows the Power Factor waveforms at decreased Non linear load connected in Distribution system. Here the power factor is maintained around unity

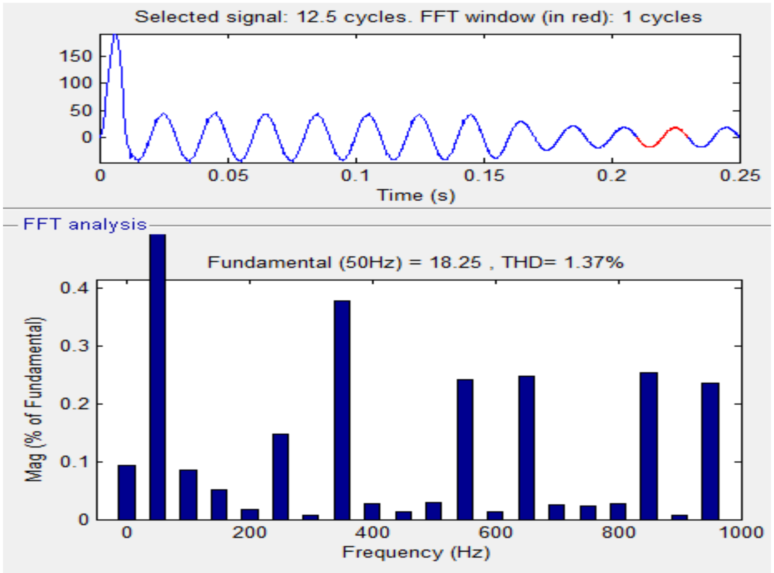

Figure 24: Source Current THD

Figure 24 shows the source current THD waveforms at decreasedNon linear source connected in Distribution system. The THD presented in load current is 1.37%.

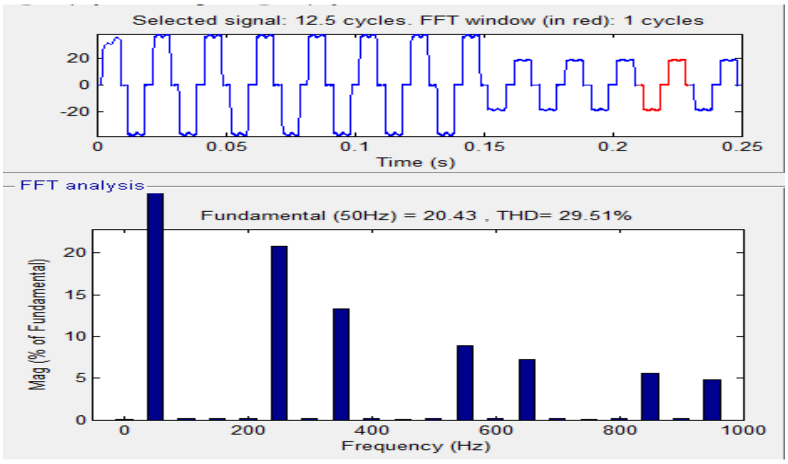

Figure 25: Load current THD

Figure 25 shows the load current THD waveforms at decreased Non linear load connected in Distribution system. The THD presented in load current is 29.51%.

Table 1: THD Comparison

Condition of the System	THD of Source current at PCC
At Constant load	1.54 %
Increment in load	3.04 %
Decrement in load	1.34 %

5. CONCLUSIONS

In industrial and domestic applications power electronic devices very much used. Due to nonlinear characteristics of PE devices draws only non linear currents from source. The source leaving harmonic component in the source current in point of common coupling (PCC). We need to compensate these harmonics with APF can mitigate harmonics in system, which includes compensating currents to system. Shunt active power filter with instantaneous harmonic power theory employed in this paper to compensate the harmonic components in source currents. APF having constant, sudden increment and sudden decrement loads were developed using Matlab/Simulink and the results for these cases were discussed in detail showing source voltage, load current, source current, APF compensating current and power factor. THD values for source currents were tabulated for different cases. Compensating currents produced by the filter, DC link voltage of VSI converter along with power factor were also discussed. THD is found to be within nominal values when APF was connected to the system with non-linear loads. Results validate the application of shunt APF for different loading conditions.

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